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Zuk

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(54) **INTELLIGENT INTEGRATED NETWORK SECURITY DEVICE**

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H04L 63/1416 (2013.01); *H04L 63/1441*
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63/0209 (2013.01); *H04L 63/0218* (2013.01)

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CPC *H04L 63/02*; *H04L 69/22*; *H04L 63/0263*
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patent is extended or adjusted under 35
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claimer.

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(57) **ABSTRACT**

Methods, computer program products and apparatus for pro-
cessing data packets are described. Methods include receiv-
ing the data packet, examining the data packet, determining a
single flow record associated with the packet and extracting
flow instructions for two or more devices from the single flow
record.

20 Claims, 9 Drawing Sheets

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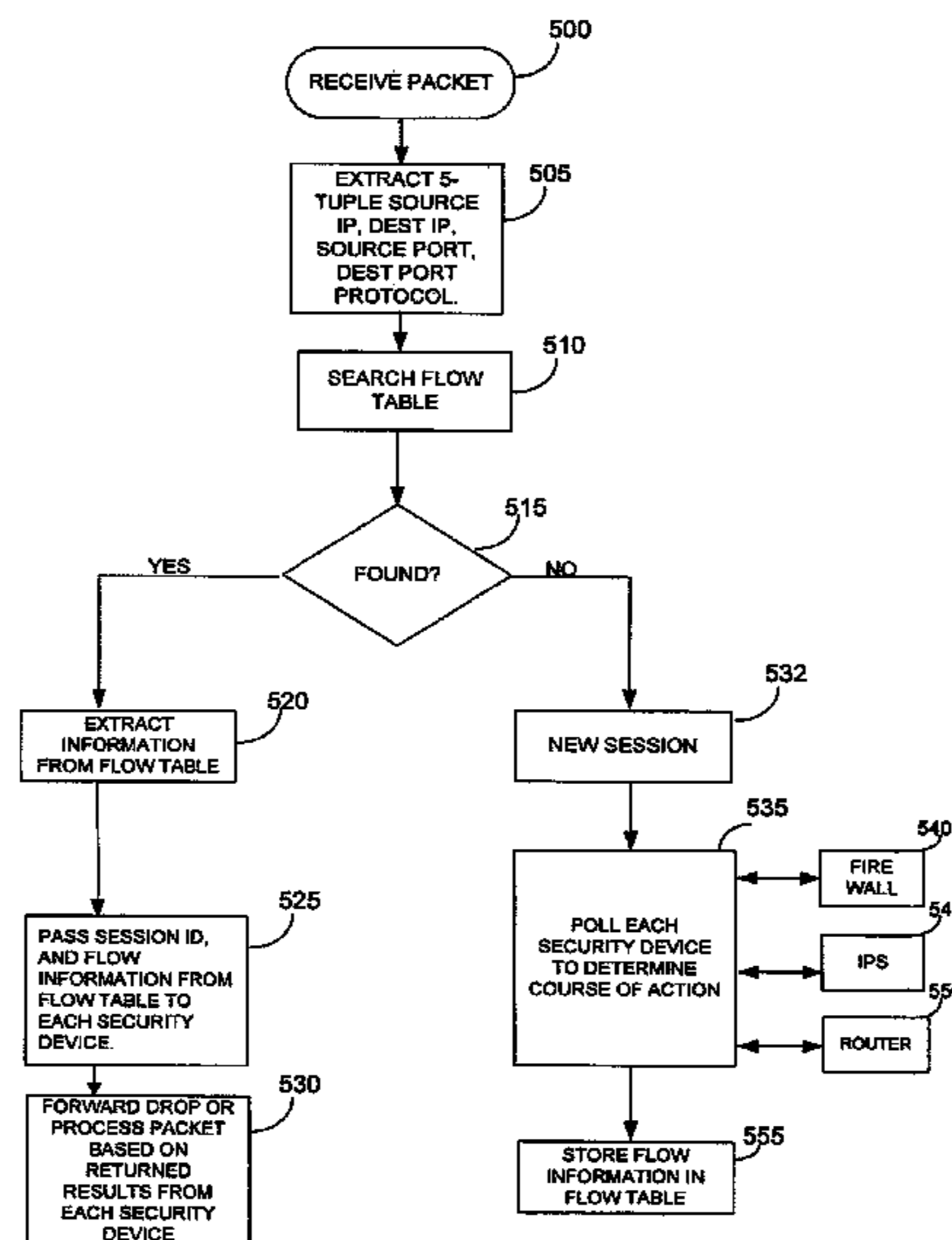
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Mar. 28, 2003, now Pat. No. 7,650,634, which is a
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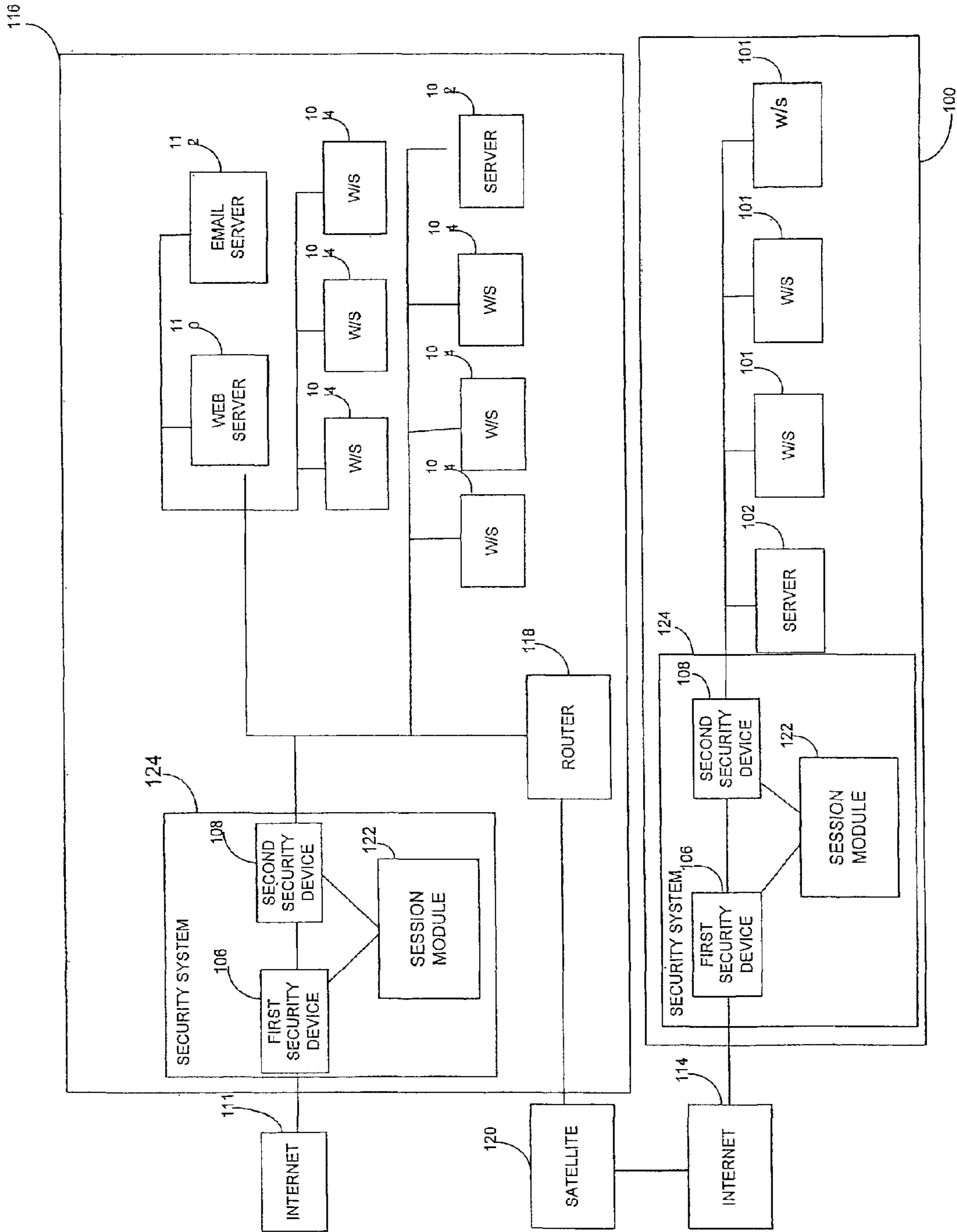


FIG. 1

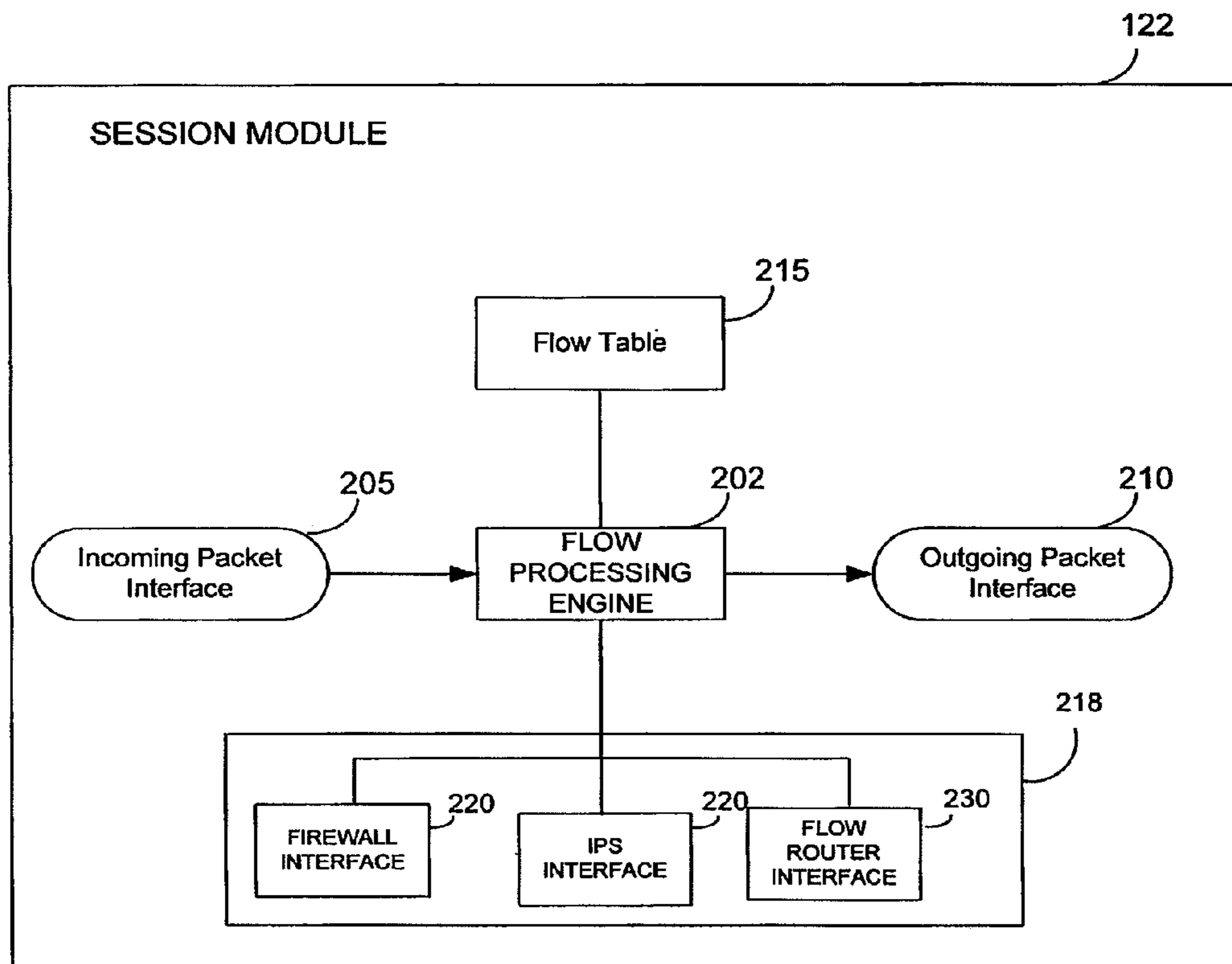


FIG. 2

305 KEY	310 SECURITY DEVICE INFO 1	315 SECURITY DEVICE INFO 2	320 SECURITY DEVICE INFO 3	325 FLOW INFORMATION
302	RECORD #1			
302	RECORD #2			
302	.			
302	.			
302	RECORD N			

FIG. 3

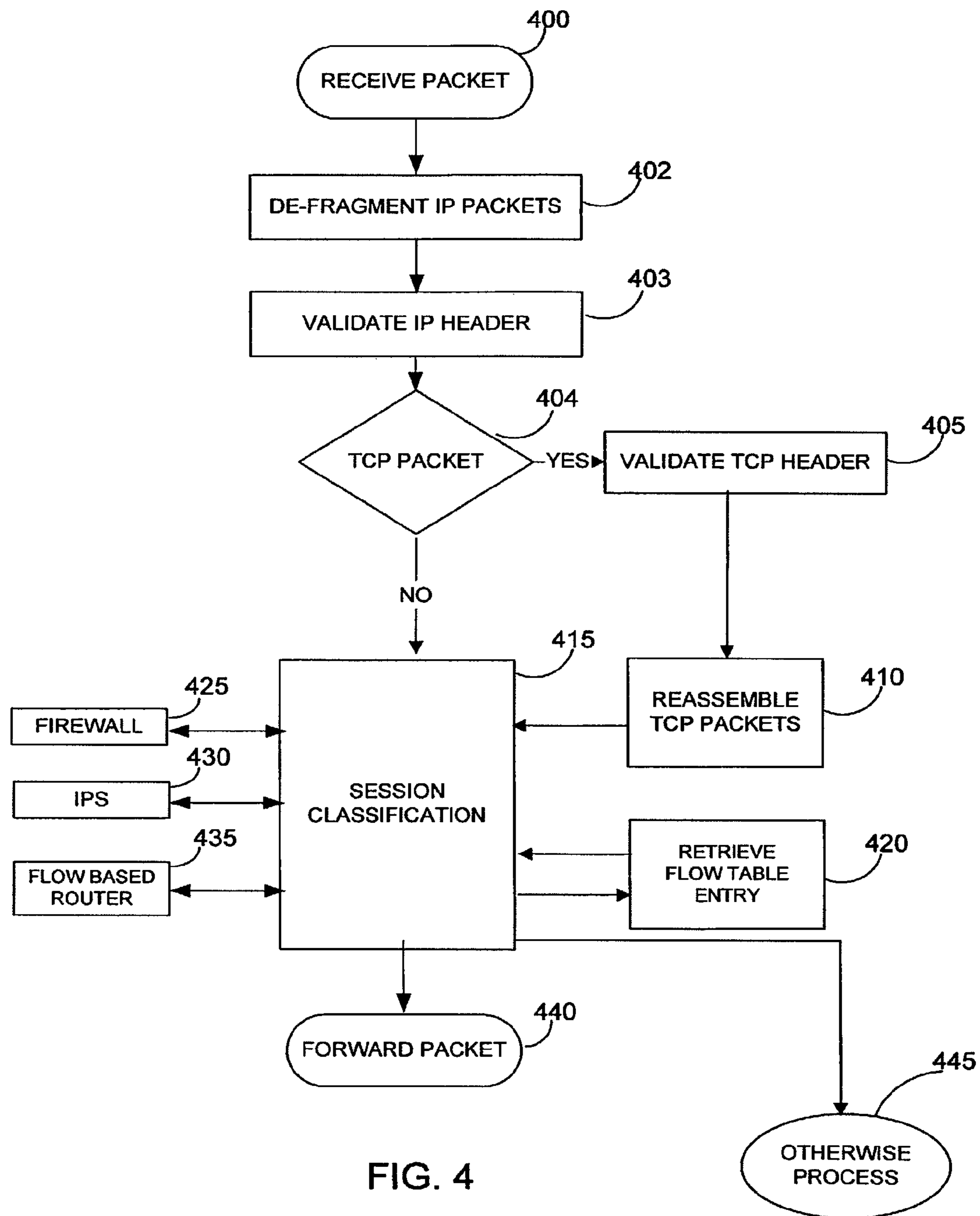


FIG. 4

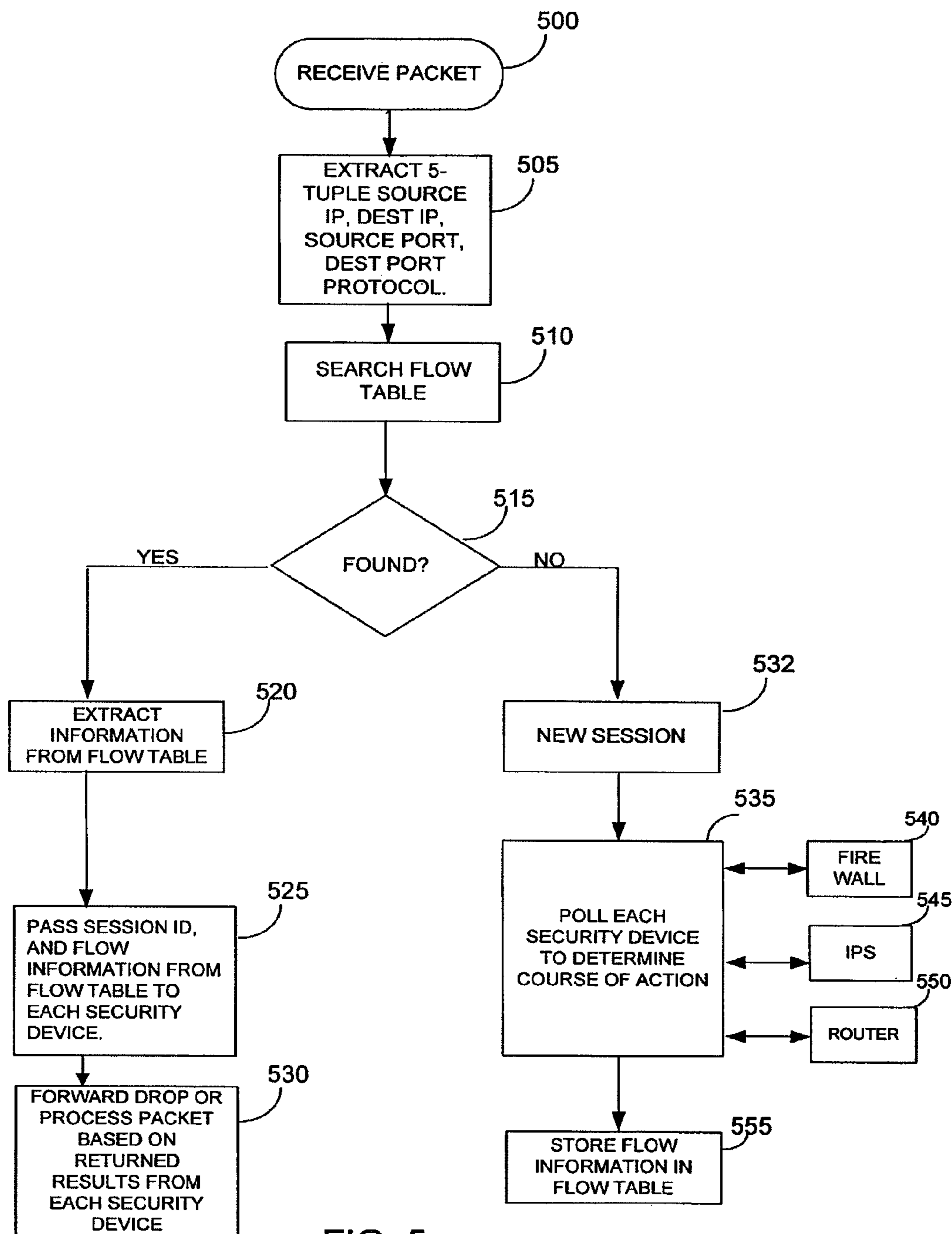


FIG. 5

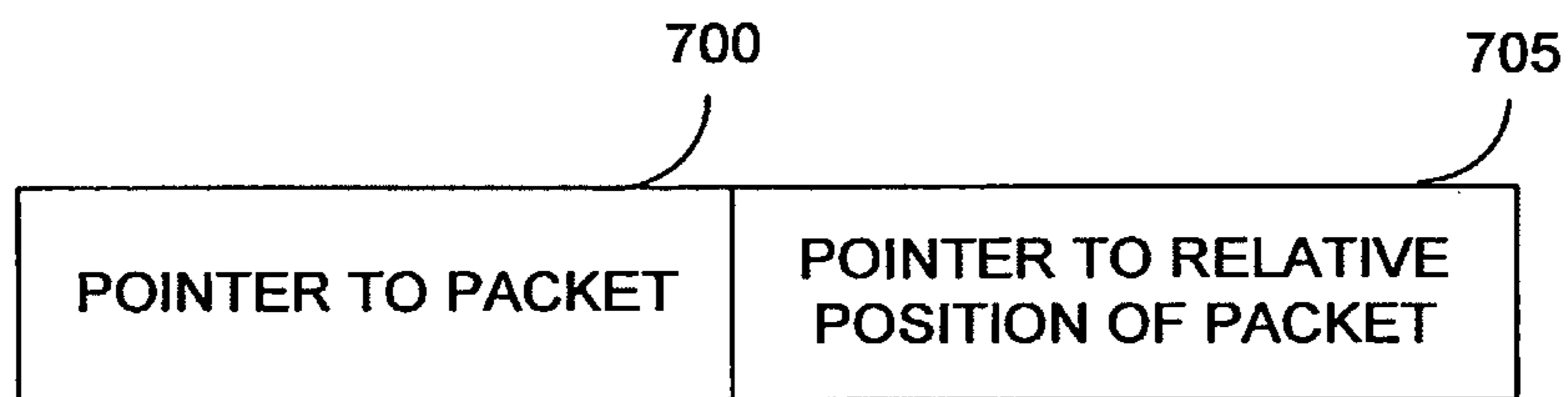


FIG. 6

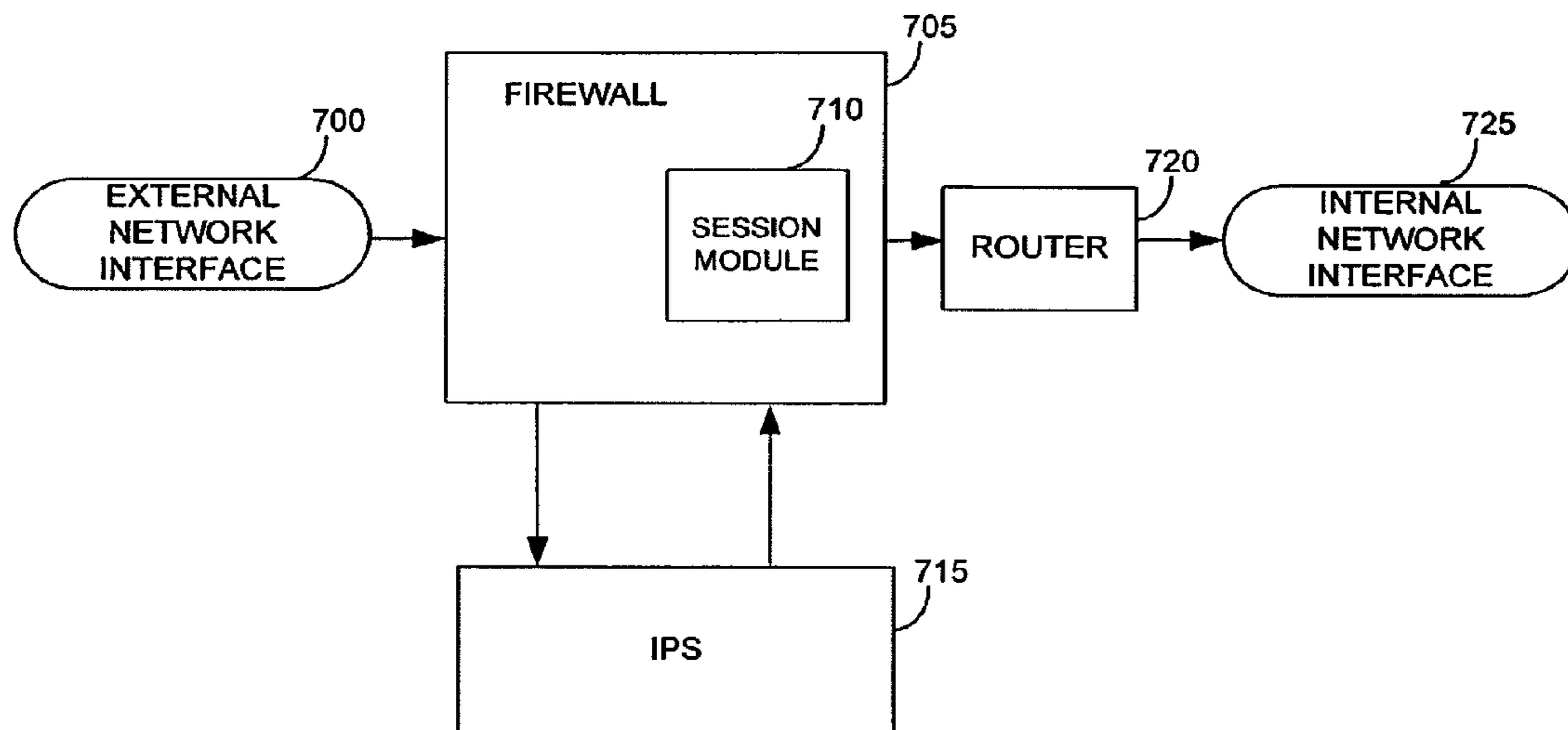


FIG. 7

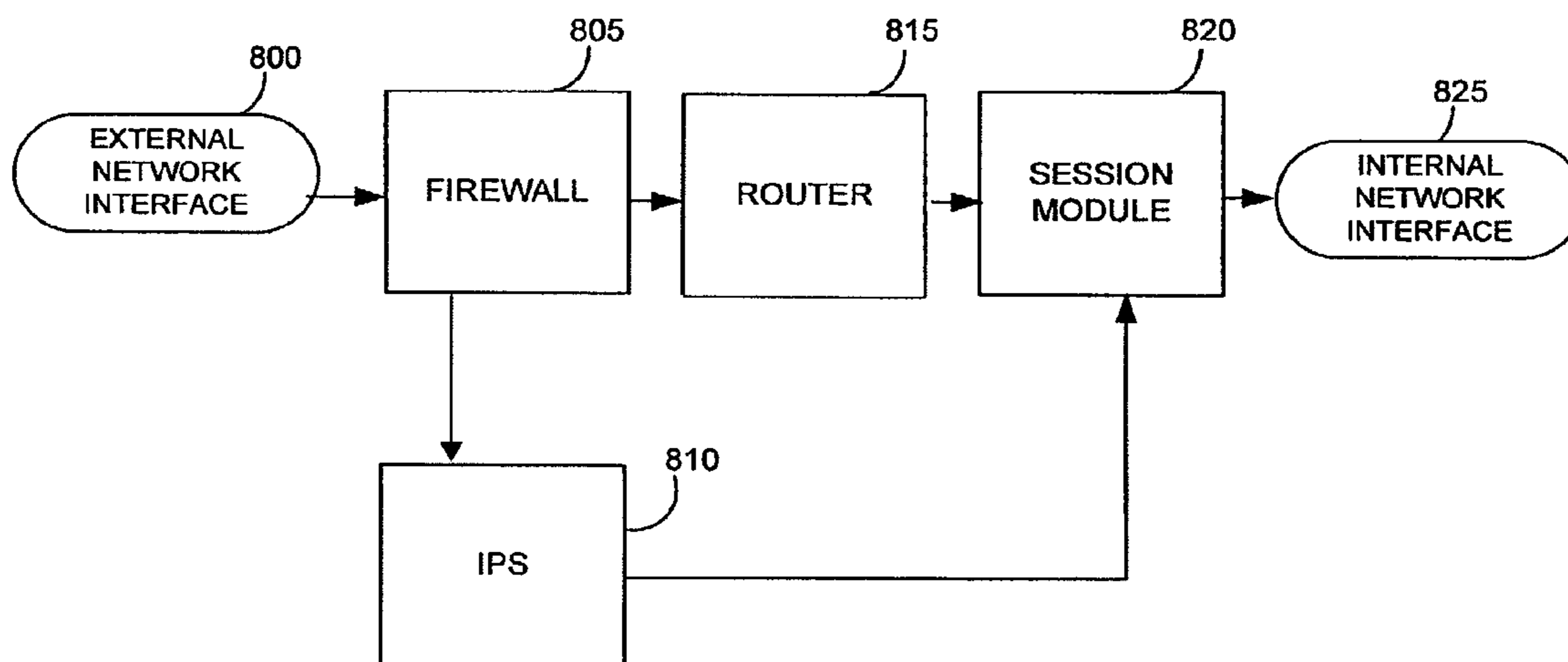


FIG. 8

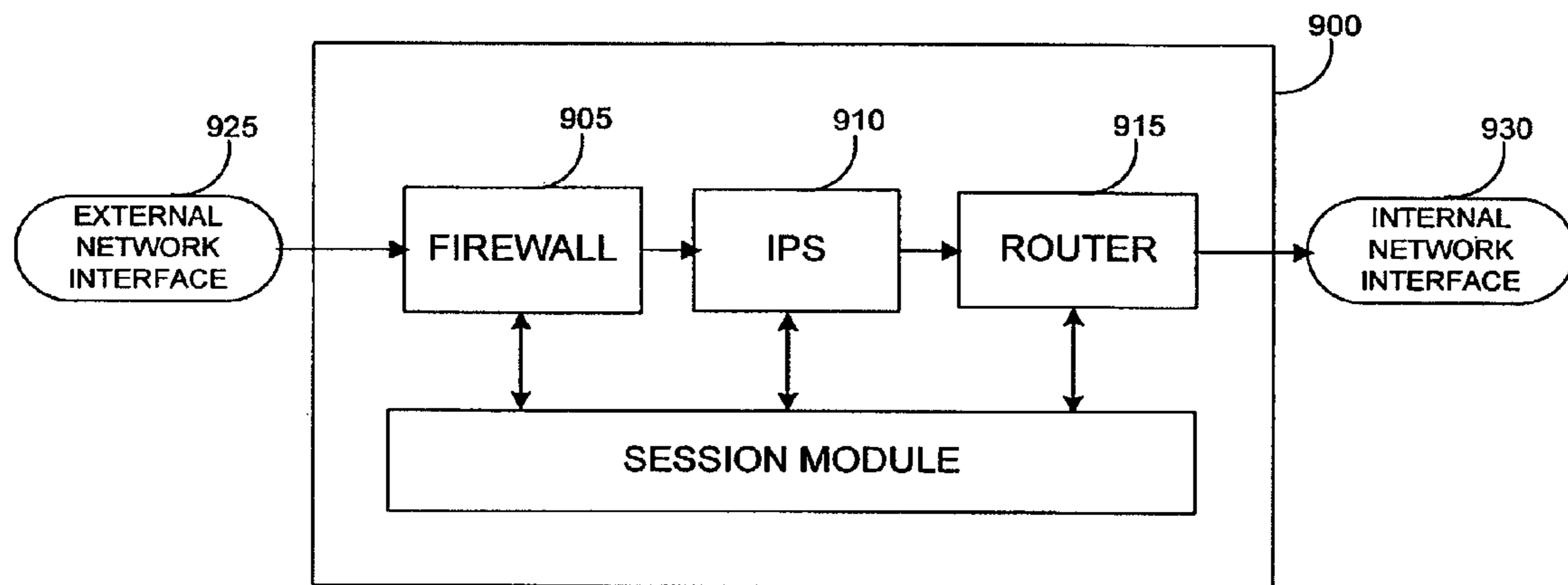


FIG. 9

INTELLIGENT INTEGRATED NETWORK SECURITY DEVICE

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation of U.S. application Ser. No. 13/616,067, filed Sep. 14, 2012, which is a continuation of U.S. application Ser. No. 12/575,997, filed Oct. 8, 2009 (now U.S. Pat. No. 8,332,948), which is a continuation of U.S. application Ser. No. 10/402,920, filed Mar. 28, 2003 (now U.S. Pat. No. 7,650,634), which is a continuation-in-part of U.S. application Ser. No. 10/072,683, filed Feb. 8, 2002 (now U.S. Pat. No. 8,370,936). The disclosure disclosures of the prior applications are considered part of (and are incorporated by reference in) the disclosure of this application.

BACKGROUND

The present invention relates to a method for controlling computer network security. Firewalls and intrusion detection systems are devices that are used to protect a computer network from unauthorized or disruptive users. A firewall can be used to secure a local area network from users outside the local area network. A firewall checks, routes, and frequently labels all messages sent to or from users outside the local area network. An intrusion detection system (IDS) can be used to examine information being communicated within a network to recognize suspicious patterns of behavior. Information obtained by the IDS can be used to block unauthorized or disruptive users from accessing the network. An intrusion prevention system (IPS) is an in-line version of an IDS. An IPS can be used to examine information as it is being communicated within a network to recognize suspicious patterns of behavior.

A flow-based router (FBR) can allow network administrators to implement packet forwarding and routing according to network policies defined by a network administrator. FBRs can allow network administrators to implement policies that selectively cause packets to be routed through specific paths in the network. FBRs can also be used to ensure that certain types of packets receive differentiated, preferential service as they are routed. Conventional routers can forward packets to their destination address based on available routing information. Instead of routing solely based on the destination address, FBRs can enable a network administrator to implement routing policies to allow or deny packets based on several other criteria including the application, the protocol, the packet size and the identity of the end system.

A packet filter can operate on the data in the network layer, to defend a trusted network from attack by an untrusted network. Packet filters can operate at the network layer to inspect fields of the TCP/IP header including, the protocol type, the source and destination IP address, and the source and destination port numbers. Disadvantages of packet filters include, speed (i.e., slow) and management in large networks with complex security policies. Packet filters alone may not provide robust protection because packet filters are not aware of the context of the given communication. In addition, packet filters do not inspect the data at the application layer making packet filters vulnerable to attempted security intrusions using the application layer.

A proxy server can operate on values carried in the application layer to insulate a trusted network from an untrusted network. In an application proxy server, two TCP connections are established: one between the packet source and the proxy

server, another between the proxy server and the packet destination. The application proxy server can receive the arriving packets on behalf of the destination server. The application data can be assembled and examined by the proxy server, and a second TCP connection can be opened between the proxy server and the destination server to relay permitted packets to the destination server. Proxy servers can be slow because of the additional protocol stack overhead required to inspect packets at the application layer. Furthermore, because a unique proxy can be required for each application, proxy servers can be complex to implement and difficult to modify for supporting new applications. In addition, because proxy servers only examine application packets proxy servers may not detect an attempted network security intrusion at the TCP or network layers.

SUMMARY

The present invention provides methods and apparatus, including computer program products, for processing data packets and for implementing computer network security.

Advantages of the invention may include one or more of the following features. The technique disclosed can be used to detect an attempted network security intrusion and potentially block the current packet associated with the security intrusion. The disclosed technique can provide robust and efficient network security and includes plural security devices but only one flow table. Network security information is obtained from other network security devices and stored in a single flow record in the flow table. The use of a single flow record to determine whether a packet should be allowed can result in faster response time.

The details of one or more implementations of the invention are set forth in the accompanying drawings and the description below. Other features and advantages of the invention will become apparent from the description, the drawings, and the claims.

DESCRIPTION OF DRAWINGS

FIG. 1 shows a network topology including a session module.

FIG. 2 illustrates a block diagram of the session module.

FIG. 3 shows the structure of a flow table.

FIG. 4 is a flowchart describing the operation of the session module.

FIG. 5 is a flowchart describing session classification.

FIG. 6 shows the quasi-reassembly information generated by the session module.

FIG. 7 shows a network topology where the session module is included in a firewall.

FIG. 8 shows a network topology where the session module operates in series with a firewall, IPS, and router.

FIG. 9 shows a network topology where a session module, firewall, IPS and router are included in a single security device.

Like reference numbers and designations in the various drawings indicate like elements.

DETAILED DESCRIPTION

FIG. 1 shows a network topology including a local area network (LAN) (100), including a server (102), several workstations (W/S) (104), and a security device 124. The security system 124 can include a session module 122 and a plurality of other security devices. In the implementation shown, the security system 124 includes two security devices, a first

security device **106** and a second security device **108**. The LAN **100** is connected to an external network e.g., the Internet (**114**), through the security system **124**. The LAN **100** is also connected to a second LAN (**116**) through a router (**118**), and satellite (**120**). Second LAN **116** includes a web server (**110**), an email server (**112**), a server **102**, several workstations **104** and a security system **124**. The computers, servers and other devices in the LAN are interconnected using a number of data transmission media such as wire, fiber optics, and radio waves. The session module **122** monitors packets being communicated within the network. In one implementation, the first security device **106** can be a firewall and the second security device **108** can be an IPS. The session module **122** can act in conjunction with the first security device **106** and the second security device **108** to facilitate the blocking of packets associated with an attempted network security intrusion.

FIG. **2** shows a block diagram of a session module **122**. The session module **122** includes an incoming packet interface **205** for receiving packets. The received packets are analyzed by a flow processing engine (FPE) **202** to determine if an attempted network security intrusion is in progress. The session module **122** also includes a flow table **215**. The flow table **215** is used to store information regarding flows associated with received packets. The session module **122** also includes interfaces to other security devices on the network. In one implementation, the session module **122** includes a firewall interface **220**, an IPS interface **225**, and a flow router interface **230**. The security device interfaces **220** are used by the session module to obtain information regarding the received packet, and information regarding the flow associated with the packet, in order to determine if the received packet should be allowed or modified. The security device interfaces **218** are also used by the session module **122** to communicate flow information required by the security devices to facilitate processing of the packet.

FIG. **3** illustrates a structure of a flow table **300**. The flow table **300** includes flow records **302** associated with current TCP/IP flows. A TCP/IP flow includes a sequence of data packets communicating information between a source and a destination in one direction. The flow records are indexed using an indexing key **305**. The indexing key **305** is used to store and retrieve the appropriate flow record associated with a received packet. In one implementation, the indexing key **305** can be a hash key and the flow table **300** can be implemented as a hash table. The session module **122** (FIG. **2**) stores instructions for two or more security devices on the network in the same flow record. In one implementation of the session module **122**, instructions for three security devices (i.e. devices **310**, **315**, and **320**) are stored in the flow record **302**. The flow record **302** can store policy information (firewall policy, IPS policy etc., to apply to the flow) as well as other information that is used by the security devices such as encryption parameters, address translation parameters, book-keeping information, and statistics. The flow record **302** can also include flow information **325** required by the session module **122** in order to decide whether the packet should be allowed. Such information can include information required to implement network policies regarding, for example connection time out, time billing, and bandwidth usage. Flows, sessions and flow tables are described in greater detail in co-pending and commonly owned patent application entitled "Multi-Method Gateway-Based Network Security Systems and Methods," and assigned Ser. No. 10/072,683, the contents of which are expressly incorporated herein by reference.

FIG. **4** is a flow diagram describing the operation of the FPE **202** (FIG. **2**). Referring now to FIGS. **2** and **4**, incoming

packets are received by the session module (step **400**). IP packets are de-fragmented (step **402**) and the IP header is validated for each IP packet (step **403**). In the validation step, the IP header associated with a given packet is extracted and the extracted IP header is inspected for fundamental flaws. Thereafter FPE **202** determines if the session is to be allowed (step **415**).

If the packet is a TCP packet (step **404**), the TCP header is validated (step **405**) and the TCP packets are reassembled (step **410**). The validation process includes extracting TCP header data and evaluating the header for fundamental flaws. The quasi-reassembly information developed in step **410** can be communicated by the session module **122** to other security devices to facilitate processing of the packet by the other security devices. Reassembly is described in greater detail below and in "Multi-Method Gateway-Based Network Security Systems and Methods."

In step **415**, FPE **202** performs session classification using the TCP/IP header data associated with a given received packet. The session module **122** can determine if the packet should be allowed based on information obtained regarding the TCP/IP flow associated with the received packet and retrieved from the flow table **420**. In addition, the session module **122** can use information returned from one of the other security devices e.g., the firewall **425**, the IPS **430**, and the flow based router **435**. Further, the session module **122** can also facilitate the operation of the security devices by communicating flow information to a respective device as required by the device to process a given packet. Finally, FPE **202** forwards the packet if the packet should be allowed (step **440**). Otherwise, the packet is otherwise processed at step **445**. Other processing can include logging particular information regarding the packet, holding the packet, modifying and/or dropping the packet. This completes the description of the operation of FPE **202**.

FIG. **5** is a flow diagram showing the steps included in session classification (step **415**). The session classification step receives a packet (step **500**) and extracts information required to determine whether the packet should be allowed. The extracted information can include the source and destination IP addresses, the source and destination port numbers, and the protocol (step **505**). The extracted information can be used to search the flow table (step **510**) in order to determine if the packet is associated with a known session flow. For a known session flow, step **510** will produce a matching flow record in the flow table (step **515**). If a matching flow record is found, the FPE **202** (FIG. **2**) can extract TCP/IP session information for the received packet (step **520**) from the matching flow record. The FPE **202** determines if the received packet should be allowed using the TCP/IP session information obtained during step **520**. More specifically, the FPE **202** extracts information from the matching flow record, and passes the information to the security devices (e.g., communicating the session ID and the TCP/IP session information as well as any other security device specific information from the flow record) (step **525**). Depending on the returned results from the security devices, the FPE **202** can forward, drop, log, store, modify or otherwise process the given packet (step **530**).

If a matching flow record is not found in the flow table during step **515**, the received packet can be associated with a new TCP/IP session (step **532**). For a new TCP/IP session, the FPE **202** can assign a session ID to the new session and the FPE **202** can communicate with the other security devices (e.g. firewall, IPS, flow router) to determine a security policy for packets associated with the new session. For example, the FPE **202** can obtain information from the firewall **540** in order

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to determine if received packets associated with the new session should be allowed. The FPE 202 can communicate with the IPS 545 in order to determine if the received packet should be blocked because it matches known attack signatures for attempted network security intrusions. The FPE 202 can obtain any network policy associated with the new session from the flow router 550. The FPE 202 can act as an arbiter between the different security devices and use the information obtained from the security devices either individually or in combination to determine if the packets associated with the new TCP/IP session should be allowed. The FPE 202 can use the information obtained from the security devices to create a new flow record and store the new flow record in the flow table (step 555). The new flow record includes the TCP/IP session information for the new session associated with the received packet and any other specific security device information. Thereafter, the FPE 202 can facilitate the processing of received packets associated with a given TCP/IP session as described above in association with FIG. 4 including communicating the session ID, TCP/IP session information and security device specific information to the security devices from a corresponding flow record.

In addition to determining if a received packet is associated with an attempted network security intrusion using the varied security devices, the session module can also perform quasi-reassembly of the received TCP/IP packets as described above in association with FIG. 4. FIG. 6 shows the quasi-reassembly information that can be generated by the session module. The quasi-reassembly information can include a pointer to a location of a given packet 600 in memory and a pointer to information containing the relative position of the packet in a flow 605. In one implementation, an IPS can perform passive TCP/IP reassembly and the pointer to the location of the packet can be used to locate the packet within the IPS. In another implementation, the pointer to information containing the relative position of the packet in the flow can be used to obtain the TCP/IP sequence number included in the TCP/IP header associated with the packet. The quasi-reassembly information can be communicated to the security devices connected to the session module 122 (FIG. 2) as required. The security devices can use the quasi-reassembly information to process the received packet.

The session module can be used in a number of different network topologies. FIG. 7 shows a network topology where a session module 710 is integrated into a firewall 705. The firewall 705 can include an interface to a router 720 and an IPS 715. The firewall 705 receives packets from the external network interface 700. The firewall 705 communicates with the IPS 715 to determine whether the received packet should be blocked based on known attack signatures. If the firewall 705 and IPS 715 determine that the packet should be allowed to pass, the firewall 705 sends the received packet to the router 720. The router 720 forwards the outgoing packet to its intended destination, using the internal network interface 725, based on the network policies stored in the router.

FIG. 8 shows an alternate arrangement for implementing computer network security using a session module. In this arrangement, the session module 820 operates in series with a firewall 805, an IPS 810, and a router 815. Packets received using the external network interface 800 are screened by the firewall 805 before being communicated to the router 815. The firewall 805 also sends information regarding the received packet to the IPS 810. The IPS 810 examines the received packet and informs the session module 820 if the received packet should be blocked based on known attack signatures. The router 815 sends the packet to the session module 820 for further processing. If the session module 820

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determines that the received packet should be allowed it forwards the received packet to its intended destination using the internal network interface 825.

The invention can be implemented in digital electronic circuitry, or in computer hardware, firmware, software, or in combinations of them. The invention can be implemented as a computer program product, i.e., a computer program tangibly embodied in an information carrier, e.g., in a machine-readable storage device or in a propagated signal, for execution by, or to control the operation of, data processing apparatus, e.g., a programmable processor, a computer, or multiple computers. A computer program can be written in any form of programming language, including compiled or interpreted languages, and it can be deployed in any form, including as a stand-alone program or as a module, component, subroutine, or other unit suitable for use in a computing environment. A computer program can be deployed to be executed on one computer or on multiple computers at one site or distributed across multiple sites and interconnected by a communication network.

Method steps of the invention can be performed by one or more programmable processors executing a computer program to perform functions of the invention by operating on input data and generating output. Method steps can also be performed by, and apparatus of the invention can be implemented as, special purpose logic circuitry, e.g., an FPGA (field programmable gate array) or an ASIC (application-specific integrated circuit).

Processors suitable for the execution of a computer program include, by way of example, both general and special purpose microprocessors, and any one or more processors of any kind of digital computer. Generally, a processor will receive instructions and data from a read-only memory or a random access memory or both. The essential elements of a computer are a processor for executing instructions and one or more memory devices for storing instructions and data. Generally, a computer will also include, or be operatively coupled to receive data from or transfer data to, or both, one or more mass storage devices for storing data, e.g., magnetic, magneto-optical disks, or optical disks. Information carriers suitable for embodying computer program instructions and data include all forms of nonvolatile memory, including by way of example semiconductor memory devices, e.g., EPROM, EEPROM, and flash memory devices; magnetic disks, e.g., internal hard disks or removable disks; magneto-optical disks; and CD-ROM and DVD-ROM disks. The processor and the memory can be supplemented by, or incorporated in special purpose logic circuitry.

The invention can be implemented in a computing system that includes a back-end component, e.g., as a data server, or that includes a middleware component, e.g., an application server, or that includes a front-end component, e.g., a client computer having a graphical user interface or a Web browser through which a user can interact with an implementation of the invention, or any combination of such back-end, middleware, or front-end components. The components of the system can be interconnected by any form or medium of digital data communication, e.g., a communication network. Examples of communication networks include a local area network ("LAN") and a wide area network ("WAN"), e.g., the Internet.

The computing system can include clients and servers. A client and server are generally remote from each other and typically interact through a communication network. The relationship of client and server arises by virtue of computer programs running on the respective computers and having a client-server relationship to each other.

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This invention has been described in terms of particular embodiments. Nevertheless, it will be understood that various modifications may be made without departing with the spirit and scope of the invention. For instance, the steps of the invention can be performed in a different order and still achieve desirable results. In addition, the session module, IPS, firewall, and router can all be incorporated into a single device such as the configuration shown in FIG. 9. Other configurations of a session module packaged with one or more security devices are also possible. Accordingly, other embodiments are within the scope of the following claims.

What is claimed is:

1. A method comprising:
 - receiving, by one or more processors of a device, a data packet;
 - examining, by the one or more processors, the data packet;
 - determining, by the one or more processors, a single flow record associated with the data packet,
 - determining the single flow record including:
 - determining a packet identifier associated with the data packet, and
 - evaluating a flow table to identify the single flow record using the packet identifier;
 - extracting, by the one or more processors, a session identifier and flow instructions, for two or more security devices, from the single flow record,
 - the session identifier identifying a session associated with the data packet,
 - the two or more security devices being included in the device;
 - sending, by the one or more processors, the flow instructions and the session identifier to respective ones of the two or more security devices to facilitate processing of the data packet;
 - receiving, by the one or more processors and from the two or more security devices, processing results,
 - the processing results being generated by the two or more security devices when processing the data packet based on the flow instructions and the session identifier; and processing, by the one or more processors, the data packet using the processing results.
2. The method of claim 1, where processing the data packet using the processing results includes:
 - dropping the packet; or
 - forwarding the packet toward a destination of the packet.
3. The method of claim 1, where the data packet is included in a flow of packets associated with the session, and where the single flow record further includes:
 - information identifying the flow of packets.
4. The method of claim 3, where sending the flow instructions and the session identifier to the respective ones of the two or more security devices includes:
 - sending, to the respective ones of the two or more security devices, the information identifying the flow of packets and the session identifier for the session.
5. The method of claim 3, where the single flow record further includes device specific information, and where sending the flow instructions and the session identifier to the respective ones of the two or more security devices includes:
 - sending, to the respective ones of the two or more security devices, the information identifying the flow of packets, the session identifier for the session, and the device specific information.

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6. The method of claim 1, where the two or more security devices include two or more of:
 - an intrusion prevention system,
 - a firewall, or
 - a router.
7. The method of claim 1, where determining the packet identifier includes:
 - extracting, from the data packet, a source address, a destination address, a source port number, a destination port number, and a protocol type associated with the data packet,
 - the packet identifier being based on the source address, the destination address, the source port number, the destination port number, and the protocol type.
8. A non-transitory computer-readable medium storing instructions, the instructions comprising:
 - one or more instructions which, when executed by one or more processors of a device, cause the one or more processors to receive a data packet;
 - one or more instructions which, when executed by the one or more processors, cause the one or more processors to examine the data packet;
 - one or more instructions which, when executed by the one or more processors, cause the one or more processors to determine a single flow record associated with the data packet,
 - the one or more instructions to determine the single flow record including:
 - one or more instructions which, when executed by the one or more processors, cause the one or more processors to determine a packet identifier associated with the data packet, and
 - one or more instructions which, when executed by the one or more processors, cause the one or more processors to evaluate a flow table to identify the single flow record using the packet identifier;
 - one or more instructions which, when executed by the one or more processors, cause the one or more processors to extract a session identifier and flow instructions, for two or more security devices, from the single flow record,
 - the two or more security devices being included in the device;
 - the session identifier identifying a session associated with the data packet;
 - one or more instructions which, when executed by the one or more processors, cause the one or more processors to send the session identifier and the flow instructions to respective ones of the two or more security devices to facilitate processing of the data packet;
 - one or more instructions which, when executed by the one or more processors, cause the one or more processors to receive, from the two or more security devices, processing results,
 - the processing results being generated by the two or more security devices when processing the data packet based on the flow instructions and the session identifier; and
 - one or more instructions which, when executed by the one or more processors, cause the one or more processors to process the data packet using the processing results.
9. The non-transitory computer-readable medium of claim 8, where the one or more instructions to process the data packet using the processing results include:
 - one or more instructions which, when executed by the one or more processors, cause the one or more processors to selectively:

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log information regarding the data packet based on the processing results,
store the data packet based on the processing results, or
modify the data packet based on the processing results.

10. The non-transitory computer-readable medium of claim **8**, where the instructions further include:

one or more instructions which, when executed by the one or more processors, cause the one or more processors to receive another data packet;

one or more instructions which, when executed by the one or more processors, cause the one or more processors to determine that a single flow record, associated with the other data packet, is not found in the flow table; and

one or more instructions which, when executed by the one or more processors, cause the one or more processors to create and store, in the flow table, a new single flow record associated with the other data packet.

11. The non-transitory computer-readable medium of claim **10**, where the other data packet is associated with another session, and

where the instructions further include:

one or more instructions which, when executed by the one or more processors, cause the one or more processors to communicate with the two or more security devices to determine a security policy for packets associated with the other session;

one or more instructions which, when executed by the one or more processors, cause the one or more processors to assign an identifier to the other session; and

one or more instructions which, when executed by the one or more processors, cause the one or more processors to store, in the new single flow record, the identifier of the other session and the security policy.

12. The non-transitory computer-readable medium of claim **8**, where the one or more instructions to process the data packet using the processing results include:

one or more instructions which, when executed by the one or more processors, cause the one or more processors to selectively:

drop the data packet based on the processing results, or
forward the data packet to a destination of the data packet based on the processing results.

13. The non-transitory computer-readable medium of claim **8**, where each security device, of the two or more security devices, includes a different one of:

an intrusion prevention system,
a firewall, or
a router.

14. The non-transitory computer-readable medium of claim **8**, where the one or more instructions to determine the packet identifier include:

one or more instructions which, when executed by the one or more processors, cause the one or more processors to extract, from the data packet, a source address, a destination address, a source port number, a destination port number, and a protocol type associated with the data packet, and

where the packet identifier is based on the source address, the destination address, the source port number, the destination port number, and the protocol type.

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15. A system comprising:

a device to:

receive a data packet;

determine a packet identifier associated with the data packet;

search a flow table, using the packet identifier, to identify a single flow record associated with the data packet; extract a session identifier and flow instructions, for two or more security devices, from the single flow record, the two or more security devices being included in the device;

the session identifier identifying a session associated with the data packet;

send the session identifier and the flow instructions to respective ones of the two or more security devices to facilitate processing of the data packet;

receive, from the two or more security devices, processing results,

the processing results being generated by the two or more security devices when processing the data packet based on the flow instructions and the session identifier; and

selectively:

drop the data packet based on the processing results,
or

forward the data packet to a destination of the data packet based on the processing results.

16. The system of claim **15**, where each security device, of the two or more security devices, includes a different one of:

an intrusion prevention system,
a firewall, or
a router.

17. The system of claim **15**, where the data packet is included in a flow of packets associated with the session, and where the single flow record includes:

information identifying the flow of packets.

18. The system of claim **17**, where, when sending the flow instructions, the device is to:

send, to the respective ones of the two or more security devices, the information identifying the flow of packets and the session identifier for the session.

19. The system of claim **15**, where the device is further to: receive another data packet;

determine that a single flow record, associated with the other data packet, is not found in the flow table; and create and store, in the flow table, a new single flow record associated with the other data packet.

20. The system of claim **19**, where the other data packet is associated with another session, and

where the device is further to:

communicate with the two or more security devices to obtain information relating to processing packets associated with the other session;

assign another session identifier to the other session; and store, in the new single flow record, the other session identifier and the information relating to processing the packets associated with the other session.

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